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EXPLORATION OF SPACE WITH SCIENTIFIC PROBES

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INTRODUCTION

In the short time since this country has been engaged in space activities, so many aspects of science and technology have evolved that it is difficult to maintain perspective as to what developments are noteworthy and which should be taken for granted. At this time I should like to focus your attention on scientific planetary probes, to offer a re-examination of the character of scientific missions to the planets, and to provide a brief progress report on the Mariner Venus probe. In this way, I hope to afford you a better appreciation of what is being done and, in particular, to make you aware of what the Mariner spacecraft now on its way to Venus may mean to you as a citizen of the United States.

NATURE OF MAN'S STIMULUS FOR DEVELOPMENT OF SCIENTIFIC SPACE PROBES

Perhaps man's greatest gifts are his desire and ability to learn. These gifts, coupled with unlimited opportunities and the freedom of choice from among these, make it possible for us to continue learning throughout life, and, indeed, throughout generations. The world about us, man himself, and objects close at hand will provide continuous study and basis for learning for years to come. The wonders and the opportunities appear boundless.

Man has a strong urge to expand his knowledge as rapidly as possible, and he is forever probing into areas of unknown. The heavens belong to each and every man with eyes to see them, and the planets are now truly an international treasure, available for conquest. Exploratory probes to other planets, when we do not know all there is to know about the planet Earth, serve to emphasize the desire of man to expand his knowledge as rapidly as possible. In spite of frequent criticism by those who question the value of such efforts to our daily living, we have seen again and again how man, by probing in this way far ahead of immediate needs, has made great discoveries. No one can say what returns may inevitably result from these scientific explorations. But it is a foregone conclusion that man's thirst for knowledge, his ability to learn, the opportunities available to him, and the consequent scientific discoveries are certain to enrich the lives of all mankind.

NATURE OF THE PROBLEM

Let us now turn from our philosophical train of thought to reality, and explore the nature of the problem of sending scientific probes into space and returning data by use of technologies already within our grasp. Because of our immediate interest in the Mariner spacecraft on its way to Venus, I should like to concentrate this discussion on the problem of reaching and exploring that planet as a typical example.

Of course, the first problem is that of launching a probe from Earth with sufficient energy to send it on its long journey to Venus. The fundamentals of rocket mechanics pertaining to orbital flights are becoming commonplace knowledge among laymen today. Flights to the moon, basically earth orbital rendezvous missions, are increasingly difficult, but are also becoming well understood. Flights from Earth to Venus involve additional complex considerations, although in principle they are similar to those involved in going to the moon. The fact that both Earth and Venus are revolving around a central body, the Sun, does provide some additional problems, however.

Venus travels in its orbit about 67 million miles from the Sun, making a complete revolution every seven and one-half months. As you know, the Earth orbits the Sun every twelve months at a distance of about 93 million miles. Because of the different rotational periods of Venus and the Earth, their positional geometry, with respect to the Sun, is cyclically repetitive every 19 months. As you may also know, there is only one trajectory each 19 months which affords an opportunity for flight from Earth to Venus with a minimum launch energy, or, in other terms, the payload is maximized for a given vehicle only once each 19 months. What you may not appreciate, however, is the rapidity with which the payload capability decreases for launch times before or after this time of minimum energy. For a typical three-stage rocket, the rate of change of payload, that is, the reduction in payload from maximum, is about 2-4 % per day. Another way of emphasizing this is that energy requirements increase so rapidly after the optimum day of launch, that in only 80 days past optimum a rocket suitable for launching a given payload to Venus would have the energy capability for launching the same payload completely out of the solar system.

Another important factor which must be taken into account for a Venus launching is the diurnal timing problem. The rotation of Earth about its axis, and the fact that the axis of the Earth is inclined some 23 1/2° with respect to the plane of the ecliptic means that only a limited period of time is available for launching each day. Trajectories are further constrained by the fact that the plane of rotation about the Sun is different for Venus than for Earth by about 3 1/2°. While this plane difference seems small, it is sufficient to require a considerable additional amount of energy. At its worst condition, Venus is about 4 million miles out of the plane of the ecliptic.

Under the constraints outlined above, launch opportunities for Venus between now and 1970 will be limited to brief periods around March, 1964; October, 1965; June, 1967; and January, 1969. Larger and more powerful rockets will expand the launch period around these optimum dates from a few days to as much as a few months (probably about three), but it does not appear likely that trips will be made to Venus at a much greater frequency. It might be worth mentioning that the problem **of launch and rendezvous for** Mars is worse, inasmuch as **its** cyclic frequency is 26 months. Not counting the opportunity in November of this year, which the United States has had to forego for technical and funding reasons, there are only three brief periods remaining for launchings to Mars before 1970.

The energy problem discussed thus far is primarily a matter of launching a spacecraft from the Earth to the orbit of another planet, although some aspects of the timing problem essential to planet rendezvous have been reviewed. It might be more proper to consider this timing problem as a guidance matter, as the angle of the trajectory and the flight path with respect to the Earth and planetary orbits is most critically affected by the time of launch. This timing, stated before, is not only a matter of the hour of the day but is very critically dependent on the time of the year. Although it might be supposed that the boost cut-off velocity would be a critical factor in trip time or arrival velocity, it is, in fact, most critical to the guidance. During the early part of a flight, the orbit in the vicinity of the Earth is extremely affected if errors in the cut-off velocity occur. For example, a one-foot per second error in a 35,000 foot per second velocity at thrust cut-off, would result in a

29,000 mile miss at Venus. An error as small as one-foot per second is very difficult to achieve with a multi-stage vehicle. Consequently, all lunar and planetary spacecraft today are designed with a mid-course motor which can make corrections to the spacecraft trajectory after sufficient tracking time has enabled a determination of its post-boost trajectory in space. These small mid-course correction systems depend on accurately orienting the spacecraft in inertial space, and in accurately burning a small rocket for a finite period of time. The necessity of precise trajectory calculations, and the very stringent requirements on proper attitude orientation and rocket performance make this system very sensitive. After a mid-course maneuver is made, tracking is necessary for a long period to ascertain whether the correction was applied properly. Other factors affecting the guidance problems are uncertainties in the astronomical unit or the exact relative positioning of the planets, uncertainties in the precise surveyed locations of Earth-based tracking stations, and such influences as solar pressure on the spacecraft. For long interplanetary trajectories, all of these factors achieve significance.

Assuming the technologies of rocketry, guidance, and the other crucial elements of attitude-control, power supply, thermal-environment control and instrumentation are in existence, perhaps the technological discipline of major consequence is that of communications. No unmanned planetary spacecraft is of particular value without a telecommunications system. To the scientist accustomed to making direct measurements in a laboratory, the integration of his instruments with such a system, complete dependence upon it for data, and the requirements it imposes for the analysis and interpretation of the data, are somewhat aggravating. To a technologist, however, just to be able to communicate from the distances of the planets is considered a justifiably significant technological achievement. In a small spacecraft of the size that can now be sent to the planets, however, there is a continuous struggle between weight, power, and the telemetry bit rate. To simplify the communications system in the spacecraft as far as possible, powerful stations have been located around the Earth, and wherever the heavy equipment can be placed on the ground to the advantage of minimizing spacecraft weight, this is done. New communications records will be set by any planetary spacecraft if it succeeds in sending back useful data from a planet.

Fortunately, the exploration of the Moon and planets need not wait for rockets big enough to send men to these bodies. The receivers and transmitters being carried by today's spacecraft are tiny and rugged with power requirements of only a few watts. With these systems messages can be sent for 50 to 100 million miles, and in some ways, it appears that it will be easier to send a clear radio message from Mars or Venus to Earth than between New York and Tokyo. This leads to an important conclusion about space exploration. The cost of transporting men and material into space will be extremely high, but the cost and difficulty of sending information through space will be comparatively low. Because of this fact, the place for unmanned spacecraft is forever established.

SECRETS OF INTERPLANETARY SPACE AND THE PLANET VENUS

The environment of space is "empty" only by Earthly standards. Actually, "empty" space is rich in energy, radiation, and fast-moving particles of great variety. Here we **are** exploring the active medium, a kind of electrified plasma, dominated by the Sun, through which our Earth and the other planets move. There is direct evidence of vast systems of magnetic fields and electric currents that are connected somehow with the outward flow of charged material from the Sun. Interplanetary spacecraft will make direct measurements of these phenomena and give us a detailed three-dimentional picture of the gravity and magnetic fields of the Earth and the Sun. Effects of this interplanetary medium on the Earth and our daily lives are beginning to be better understood. Communications problems caused by magnetic storms, and other

Sun-Earth relationships figure importantly in our earthly environment. Of course all unmanned and manned spacecraft must travel through this environment, and safety to the men in forthcoming manned flights makes it even more imperative that we thoroughly understand the environment of interplanetary space.

Turning now from the interplanetary medium through which spacecraft must journey before reaching a planet, let us consider the mysterious planet Venus in more detail. Although man has studied Venus through the centuries, he has accumulated relatively little in the way of indisputable scientific information. A major problem in studying Venus is that its surface is continually covered by a dense blanket of clouds. Therefore no man, by any means whatever, is certain to have examined its surface, and the only hope appears to be with direct flights by planetary probes.

An outstanding feature of Venus is its brightness. This is due partly to its highly reflective cloud layer, but also because it is close to the sun. Venus is the third brightest object in our sky after the sun and the moon. Its reflectivity is measured to be about 60% as compared to 7% for our moon. Because its orbit is inside the orbit of earth, however, when it is nearest to earth, it appears as a crescent and does not seem as bright as it would otherwise be.

One of the puzzling features of Venus is the changeable dark and light markings that appear in its cloud layer.

Scientists have speculated that these markings may be breaks in the clouds, but as yet there is little evidence of any regularity.

Spectrographic studies seem to indicate that Venus atmosphere contains carbon dioxide, nitrogen, but probably little free oxygen or water vapor. Measurements in the infrared region of the electro-magnetic spectrum indicate that temperatures of -38° Farenheit exist somewhere in the atmosphere. The micro-wave regions, however, show temperatures of 615° Farenheit, believed to be at or somewhere near the surface. The surface temperature, however, is still in doubt and this is one of the important mysteries.

Because so little is known of the planet, there are many theories which have been advanced. One of these explains a Venusian ionosphere with thousands of times the electron density of the earth which gives the impression that the planet is extremely hot. Another theory explains the high temperature on the basis of a "greenhouse" effect in which the sun's energy is tracked beneath the dense clouds. A third theory holds that the surface of Venus is heated by friction produced by high winds and dust clouds. The most detailed measurements made on Venus in recent months were conducted with large radio telescopes. These radar measurements provide data which suggest that Venus rotates at a very slow rate, perhaps only once each Venusian year of about 225 days. If this is the case, it would mean that Venus always keeps the same side facing the sun in much the same way that our moon keeps its same side always facing the earth.

The little evidence accumulated to date indicates that Venus is not likely to be a desirable habitat for life as we know it. However, from a scientific sense, it is the uncertainties which make it attractive for exploration.

MARINER 2 REPORT

Mariner 2 was launched from Cape Canaveral on August 27, 1962, with an aiming point 10,000 miles from the surface of Venus. This spacecraft is a 447 pound system evolved from the Ranger which it resembles in many respects. It has a hexagonal space frame housing a liquid fuel rocket motor for trajectory correction, and 6 modules containing the attitude control system, electronic circuitry for the scientific experiments, power supply, battery and charger, data encoder and command subsystem, digital computer and sequencer, and radio transmitter and receiver. Two rectangular solar panels are mounted on the structure with sun sensors and attitude control jets on the exterior of the base of the hexagon. An omni-directional antenna and scientific experiments are attached to a super-structure framework. A parabolic high gain antenna is hinge-mounted below the base hexagon. The high gain antenna and the spacecraft fold to allow the spacecraft to fit within the Atlas-Agena shroud during the launch phase. In its launch position, the spacecraft is about 5 feet in diameter at the base and about 10 feet in height. In its cruise position with solar panels extended, it is about 16½ feet in span.

It contains five interplanetary experiments that report continuously 24 hours a day to Deep Space Instrumentation Facilities stations at three points around the world, and it carries two planetary experiments designed to function as the spacecraft flys by Venus. The special planetary instruments, infrared and microwave radiometers, are to scan the whole disc of the planet as the spacecraft approaches, passes, and travels away from Venus. This is a principal reason the fly-by rather than impact mission was chosen: To provide maximum time for planetary observations close to Venus. Additional advantages of the fly-by mission are that both the sunlit and dark regions of the planet may be seen, and the period of continuing interplanetary measurements after closest approach may provide a basis for verifying any unique data received from the vicinity of the planet. This would be made possible from the data gathered before and after the fly-by.

Continued tracking information now indicates that Mariner 2 will be about 20,900 miles from the surface of Venus at closest approach to the planet on December 14. The spacecraft will pass through the target area extending from 5,000 to 40,000 miles from Venus - well within the region where the scientific-planetary experiments are expected to be very effective.

As stated earlier, the Mariner was launched from Cape Canaveral on August 27, 1962. After 9 days of tracking, it was determined that Mariner would miss the planet by a distance of 233,000 miles if no flight path correction were applied.

Launch dispersions which could result in missing the planet by 500,000 miles were to be expected - hence, the mid-course correction motor on the spacecraft had been designed with a capability to correct the flight path, so that the spacecraft would come within the desired target area at the planet.

On September 4, the midcourse correction calculated to hit an aiming point 9,000 miles from the surface of the planet was carried out. Although telemetry during the midcourse correction phase of the flight was not sufficient for a complete evaluation of system performance, all indications were that the maneuver was successfully completed.

Following the midcourse correction, it was pointed out that because the velocity change was so small compared to the speed of the spacecraft, many days of tracking would be required to determine the effect of the correction on the trajectory.

Before the midcourse correction, the spacecraft was going too slow - by about 45 miles an hour - in relation to its velocity around the sun of 60,117 miles an hour. The precise velocity change required an increase in velocity of 45 miles an hour. Refined data now indicate that the actual velocity added was 47 miles per hour, or two miles an hour faster than desired.

The new miss distance of 20,900 miles, plus or minus 3,000 miles, was calculated after nearly five weeks of continuous tracking following the midcourse correction. No cause is known for the slight overcorrection.

Mariner will pass close to the center of the target area for which the planetary instruments were designed to operate. This pie-shaped target area is on the sunlit side of the planet and extends from about 5,000 to 40,000 miles above the surface of Venus.

The interplanetary experiments, all of which will also operate in the vicinity of Venus, were chosen on the basis of their planetary value as well as for their interplanetary measurements.

I would now like to outline these experiments briefly, and give you some idea of the kinds of information that are being gathered.

MAGNETOMETER

One of the primary scientific objectives in measuring magnetic fields in interplanetary space is to determine the magnitude and direction of the steady field component. The Mariner makes such measurements which are fundamental to a theoretical understanding of the relation between the motion of charged particles and the magnetic field which surrounds them, especially with respect to the plasma which flows away from the sun and affects the solar magnetic field. In addition, the magnetometer is expected to measure the magnitude of any magnetic field that Venus may have. With these measurements it may be possible to draw some conclusion about the interior of the planet as well as about its radiation belt and aurorae.

The Mariner 2 has already provided important fundamental magnetic field data which, when combined with Pioneer 5 results, provides a much better knowledge of the interplanetary fields and solar effects. The Mariner has indicated a typical steady state transverse component of ten gamma or less, and it has clearly shown how the transverse field becomes large (as high as 25 gamma) during geomagnetic storms. In addition to this, the Mariner 2 has provided information on the steady interplanetary field indicating that the radial component is apparently more stable, even under storm conditions, and that there are quiet times when the radial component from the sun is essentially constant.

HIGH ENERGY RADIATION EXPERIMENT

An ion chamber and particle flux detectors are included to measure charged particle intensity and distributions in interplanetary space and in the vicinity of Venus. All these detectors are still functioning properly and are reporting data. These instruments are able to detect fluxes of particles, primarily cosmic rays, with an objective of learning how cosmic rays are modulated by solar activity. When data from these radiation instruments are combined with the magnetometer and solar plasma data, it is expected that results will contribute significantly to the knowledge of hazards to manned space flight. Thus far, measurements from the ion chamber have indicated an average radiation level as expected, corresponding to about 1.1 milliroentgen per hour (about 100 times the cosmic ray intensity at the surface of the earth).

COSMIC DUST DETECTOR

Cosmic Dust Detector is carried aboard the Mariner 2 to measure the density and direction of cosmic dust particles. Such measurements have been made on earth satellites and sounding rockets many times before, but this is the first time direct data have been obtained on cosmic dust in space. It has been reported by measurements thus far that the flux of interplanetary dust particles is at least one thousand times less in interplanetary space than in the near vicinity of the earth. The cause of this is unknown, but leads to interesting speculation about the influence of the earth and moon at attracting debris from space.

SOLAR PLASMA DETECTOR

A solar plasma spectrometer aboard the Mariner 2 measures the intensity of low energy protons from the sun. Such charged particles are believed to stream outward omni-directionally into space from the face of the sun. The solar plasma interacts with magnetic fields, therefore measurements by this experiment combined with data from the magnetometer will greatly increase our knowledge of how the sun sends out plasma. Preliminary data from the Mariner indicate abrupt changes in the velocity and intensity of solar winds, and corrulated affects on the magnetic fields in space. Measurements show that the particle energies generally range from about 750 electron volts to 2500 electron volts, although some plasma with an energy of 3225 electron volts has been observed. These variations almost certainly were the results of events on the sun, but the exact nature of these events is not yet understood.

SUMMARY

In summary, I have reviewed with you the aspects of a planetary mission to Venus which I believe are important to understand, and will help you to appreciate the significance of such an effort. The Mariner 2 is now on its way and is returning unique information to earth on the mysterious environment in space as it speeds on a 180 million mile journey to Venus. If it survives the rigors of this trip, and successfully transmits data from the vicinity of the planet at closest approach on December 14, it will have set many new records and greatly extended man's knowledge of the space about our earth and its nearest neighbor Venus. Many factors make this Venus mission extremely difficult --- the precise requirements for launch, the rocket booster capability, the long flight time and the resultant demands on the spacecraft, it subjection to a prolonged variation in temperature and hazards of the interplanetary environment, and the problem of transmitting a considerable amout of information over an extreme range.

If the Mariner 2 successfully completes this mission, the

United States will have accomplished a noteworthy first of all time. When one considers the millions of years the planets have been observed by man, wished for, worshipped, and otherwise studied, it is truly a significant privilege for each of us to be able to participate on a real time basis, in the exploration of Venus.